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OBSERVATION TEST OF EXTERNAL TRACER AMMUNITION

John L. Miles, Jr.

Human Engineering Laboratory
Aberdeen Proving Ground, Maryland

February 1975

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As a preliminary study of the utility of one concept of "external tracer," five types of chemically coated ball ammunition (which, when fired, left visible vapor trails to mark projectile trajectory) were compared with 7.62mm M62 tracer, 5.56mm M196 tracer and 7.62mm ball ammunition on two measures of observation. Twenty infantrymen reported after each of 80 single rounds whether tracer was detected and which of three targets 400 meters downrange was engaged.

Standard tracers (M62 and M196) were associated with substantially more accuracy in ammunition and target identification than external tracers. Only when observers in daylight were located directly behind the weapon firing were they able to detect external tracer with an

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accuracy approaching that of standard tracer.

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Technical Memorandum 5-75

OBSERVATION TEST OF EXTERNAL TRACER AMMUNITION

John L. Miles, Jr.

Technical Assistance

William M. Robinson

February 1975

APPROVED: John D. Weisz
JOHN D. WEISZ
Director
U. S. Army Human Engineering Laboratory

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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INTRODUCTION

One of the current trends in the development of new small arms for the Infantry is toward smaller-caliber weapons. While several advantages are claimed when projectile size is reduced, there is at least one significant disadvantage: producing a tracer. In the days when the M1 rifle (.30 caliber) and the M14 rifle (7.62mm) were the primary infantry weapons, production of a satisfactory tracer was relatively simple. A cavity in the rear of the projectile was filled with a pyrotechnic material which ignited after the projectile was fired and produced a visible trace for 900-1,100 meters (depending on such characteristics as the age of the ammunition and the climatic conditions under which it was viewed). When the Army adopted the M16 rifle, a 5.56mm tracer (M196) was made by the same technique; but there is a consensus that it is neither as bright nor as long-lasting as the larger-caliber tracer, and a field test comparing both on the same terrain found significant performance differences (6). Attempts to use the same technology for developing a flechette tracer have met with even less success (4, p. G-1).

A private business firm, through an unsolicited proposal to the U. S. Army Small Arms Systems Agency (USASASA), proposed a new technique for producing tracer. The essence of the proposal was that (rather than requiring a cavity for pyrotechnic material in the rear of the projectile[1]) standard ball ammunition could be subjected to a light coating of an organic material[2] which would fluoresce inflight due to aerodynamic heating. The material had originally been developed in a program to reduce the fouling of a weapon bore caused by firing.[3] Incidental to its testing for that purpose, it was observed that projectiles coated with the substance appeared to leave a "smoke or vapor" trail marking their trajectory.

Because it appeared that, if successful, the Kotagun technique for producing a visible tracer would not only be inexpensive, but also applicable to small caliber projectiles, USASASA requested that the Human Engineering Laboratory (HEL) conduct a field experiment to "...establish the basic feasibility of the Kotagun approach." (7, p. 2)

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1 a primary cause of ballistic mismatch between ball and tracer ammunition

2 trade-named "Kotagun"

3 personal communication from Dr. John Bernath, Director of Research, DuKote Corporation, Los Angeles, California.

METHOD

Range Layout

Previous research (4) has shown that offset (i.e., the distance that an observer is removed laterally from the weapon firing) has an effect on an observer's detection of trace phenomena. To see whether and how these phenomena might appear in observations of external tracer, the test range was constructed with all firing weapons in one location at the right of the range. Five observation positions (OP) 15 meters apart were established in a line behind the weapon position. At each OP a standard wooden student chair and a 7-foot tower were emplaced (Figure 1). Two M14 rifles and two M16 rifles[4] were placed in rigid mounts (4, p. F-3) and covered with a wooden enclosure so that subjects could not see them nor see where they were aimed. The weapons were fired electrically from a remote position. Three E-type silhouette targets were nailed to 2x4s and emplaced 10 meters apart at a range of 400 meters from the line of observer positions. The right-most target (T_3 in Figure 2) was directly on line with the center of the weapons enclosure. The targets were illuminated by flashlights during the night observation test.

Subjects

Two groups of 10 enlisted men from the 82d Airborne Division who were on temporary duty at Aberdeen Proving Ground participated as subjects in the tests described below.

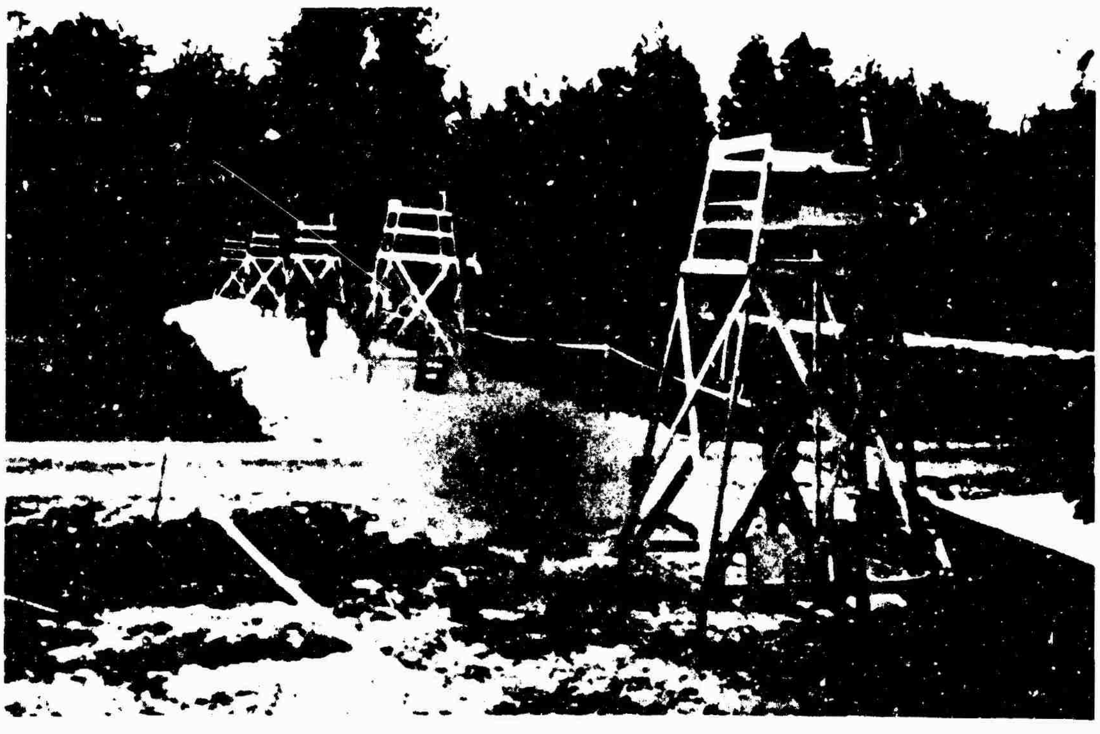
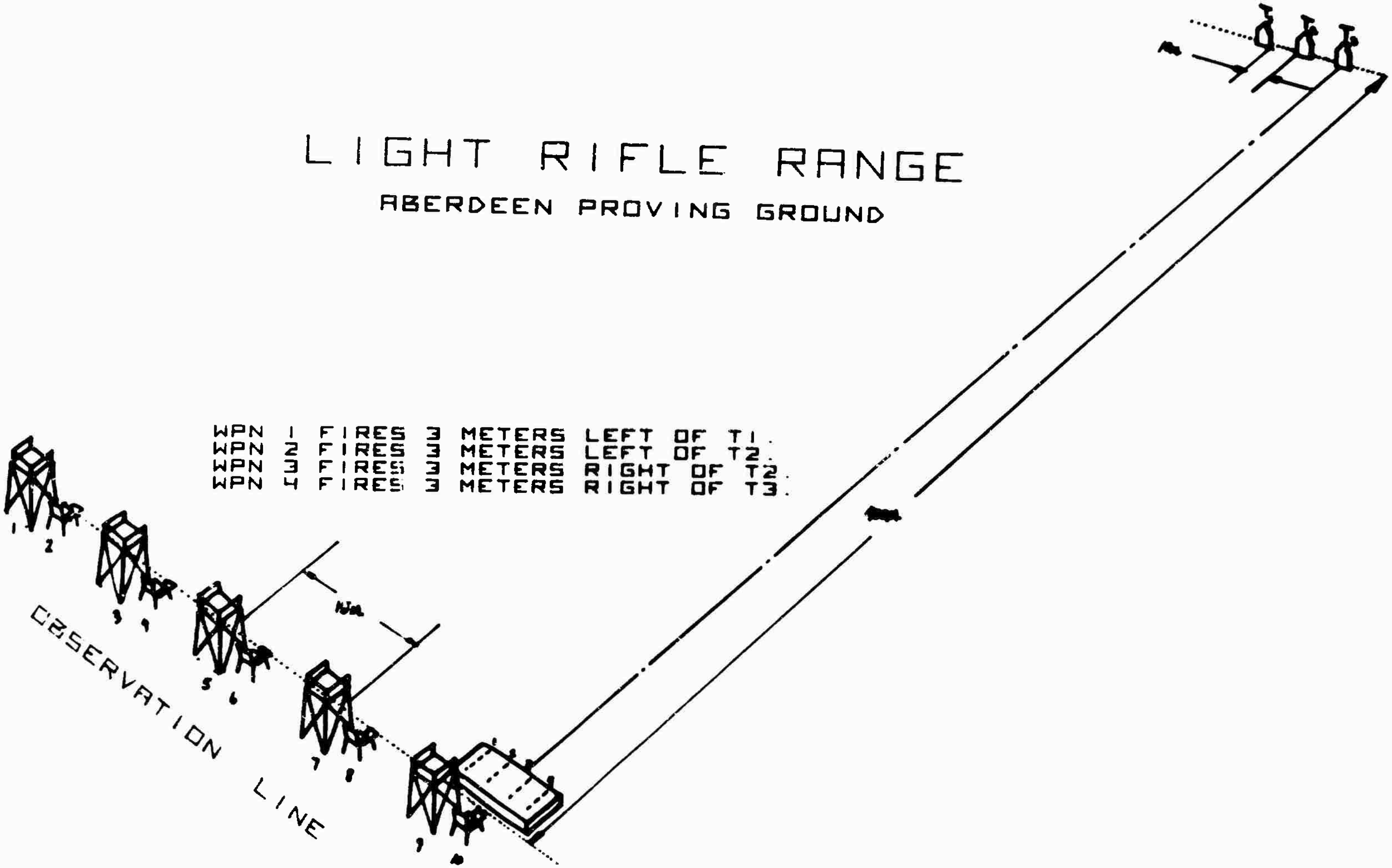


Figure 1. Photograph of observation line.

[4]Because the effect, if any, of alternately firing Kotagun and standard ammunition from a single weapon was not known, one each of the M14 and M16 weapons fired only standard ammunition.



Drawing by Paul Ellis

Figure 2. Diagram of light rifle range.

Procedure

The first group of 10 subjects received the instructions and demonstration described in Orientation 1 (p. 38). Their first observation test began approximately 1100 hours on 26 September 1972 under bright, hazy light conditions. Their second began approximately 2100 hours that night. Mean ambient illumination during the night test was 5.5×10^{-4} foot-candles (S.D. = 1.3×10^{-4} foot-candles).[5] The second subject group received the instructions and demonstration described in Orientation 2 (p. 40). They participated only in a daylight observation test, which began approximately 1100 hours on 27 September 1972 under dull, overcast light conditions.

Each of the three observation tests consisted of 10 rounds of each of eight different types of ammunition and was conducted in the same manner. The 10 subject observers were randomly assigned to initial observation positions. After every eight rounds of the test, each observer moved to a different OP. By the end of each test, each subject had observed one round of each type of ammunition from each OP. Subject number, OP number and sequence of ammunition type were counterbalanced as shown in Figure 3. Ammunition types are listed in Table 1 and are further described in Appendix A. Subjects recorded their observations in booklets issued at the beginning of each test, completing one page (Figure 4) for each round fired. Hence, for each round there were four dependent variables:

1. Accuracy of identification of tracer.

2. Confidence in correct identification of ammunition type.

3. Accuracy of identification of target engaged.

4. Confidence in correct identification of target engaged.

TABLE 1

Ammunition Types Used in External Tracer Test

A -	7.62mm ball, M80
B -	7.62mm tracer, M62
C -	7.62mm Extra-Heavy Kotagun Red
D -	7.62mm Super-Heavy Kotagun Red
E -	5.56mm tracer, M196
F -	7.62mm Extra-Heavy Kotagun White
G -	5.56mm Extra-Heavy Kotagun Red
H -	7.62mm Extra-Heavy Kotagun Orange

[5]based on photometric readings taken at the start of the test and every 15 minutes thereafter.

Observer Position

Round Number and Ammunition Type	1	2	3	4	5	6	7	8	9	10
1 A 2 B 3 C 4 D 5 E 6 F 7 G 8 H	Obs. No. 1	Obs. No. 2	Obs. No. 3	Obs. No. 4	Obs. No. 5	Obs. No. 6	Obs. No. 7	Obs. No. 8	Obs. No. 9	Obs. No. 10
9 B 10 D 11 A 12 F 13 C 14 H 15 E 16 G	Obs. No. 2	Obs. No. 4	Obs. No. 6	Obs. No. 8	Obs. No. 10	Obs. No. 1	Obs. No. 3	Obs. No. 5	Obs. No. 7	Obs. No. 9
17 C 18 A 19 E 20 B 21 G 22 D 23 H 24 F	Obs. No. 3	Obs. No. 6	Obs. No. 9	Obs. No. 1	Obs. No. 4	Obs. No. 7	Obs. No. 10	Obs. No. 2	Obs. No. 5	Obs. No. 8
25 D 26 F 27 B 28 H 29 A 30 G 31 C 32 E	Obs. No. 4	Obs. No. 8	Obs. No. 1	Obs. No. 5	Obs. No. 9	Obs. No. 2	Obs. No. 6	Obs. No. 10	Obs. No. 3	Obs. No. 7
33 E 34 C 35 G 36 A 37 H 38 B 39 F 40 D	Obs. No. 5	Obs. No. 10	Obs. No. 4	Obs. No. 9	Obs. No. 3	Obs. No. 8	Obs. No. 2	Obs. No. 7	Obs. No. 1	Obs. No. 6

Figure 3a. Experimental design.

Observer Position

Round Number and Ammunition Type	1	2	3	4	5	6	7	8	9	10
41 F 42 H 43 D 44 G 45 B 46 E 47 A 48 C	Obs. No. 6	Obs. No. 1	Obs. No. 7	Obs. No. 2	Obs. No. 8	Obs. No. 3	Obs. No. 9	Obs. No. 4	Obs. No. 10	Obs. No. 5
49 G 50 E 51 H 52 C 53 F 54 A 55 D 56 B	Obs. No. 7	Obs. No. 3	Obs. No. 10	Obs. No. 6	Obs. No. 2	Obs. No. 9	Obs. No. 5	Obs. No. 1	Obs. No. 8	Obs. No. 4
57 H 58 G 59 F 60 E 61 D 62 C 63 B 64 A	Obs. No. 8	Obs. No. 5	Obs. No. 2	Obs. No. 10	Obs. No. 7	Obs. No. 4	Obs. No. 1	Obs. No. 9	Obs. No. 6	Obs. No. 3
65 F 66 C 67 H 68 E 69 G 70 B 71 D 72 A	Obs. No. 9	Obs. No. 7	Obs. No. 5	Obs. No. 3	Obs. No. 1	Obs. No. 10	Obs. No. 8	Obs. No. 6	Obs. No. 4	Obs. No. 2
73 E 74 B 75 G 76 D 77 H 78 F 79 C 80 A	Obs. No. 10	Obs. No. 9	Obs. No. 8	Obs. No. 7	Obs. No. 6	Obs. No. 5	Obs. No. 4	Obs. No. 3	Obs. No. 2	Obs. No. 1

Figure 3b. Experimental design.

16:17	23	61	64	67	70

ROUND NO. 34

QUESTIONS	OBSERVATIONS				
1. Was this round tracer or ball ? Circle one:	Tracer	Ball			
2. How sure are you ? Circle one:	No Idea	Guess	Think So	Fairly Sure	Sure
3. At which target on the range was it fired ? Circle one:	Left	Middle	Right	OR	Couldn't Tell
4. How sure are you ? Circle one:	No Idea	Guess	Think So	Fairly Sure	Sure

Figure 4. Sample page from subject's answer booklet.

RESULTS

General

An analysis of variance was performed on each of the four dependent variables, comparing day and night performance (Table 2) and subject group performance (Table 3). Data points for the analyses of ammunition identification were generated by comparing the actual event with the subject's report of it and assigning a 1 where they agreed and a 0 where they differed.[6] Data points for the analyses of target identification were determined by assigning the value 1 when the subject correctly identified the engaged target, 2 when he chose a target adjacent to the one engaged, 3 when he selected one of the flank targets when the other was engaged, and 4 where he responded "Couldn't tell." Data points for the analyses of confidence responses were the interval numbers zero to five assigned to the terms "No idea" to "Sure" respectively.[7]

As can be seen from Tables 2 and 3, ammunition type was a significant main effect in all analyses of all dependent variables. In all cases, the standard tracers were themselves more correctly detected and permitted more correct target identifications than the Kotagun munitions. Subjects' confidence in those responses was also significantly higher when the standard tracers were fired.

In all but one of the ANOVAs there were highly significant first-order interactions among the independent variables. The existence of these interactions tends to limit the generality of effects of the independent variables (5, p. 350). Consequently, it is necessary to examine the dependent variables under simultaneous influence of the independent variables.

Ammunition Identification

The percentages of rounds correctly identified as tracer are shown as a function of observation position (see Figure 2) and ammunition type in Figures 5 through 7. These figures show that (1) at night the Kotagun munitions were not detected and (2) in daylight, they approach the detectability of pyrotechnic tracer only at a position behind the firing weapon. The average percent of correct detections of all types of tracer by Group 1 was 25 percent. The average for Group 2, which had different training and observed under more propitious illumination conditions, was 46 percent. The difference between the two groups is significant beyond the .001 level ($t = 9.32$, $df = 1598$). Inasmuch as the performance of Group 2 is more representative of that of troops trained in the detection and use of Kotagun tracer, their observations were "normalized"[8] and are shown in Figure 8 as a function of lateral offset from the weapon firing. The 120 meters shown on the absicca represents an approximate squad front across open terrain (1, p. 31) with a weapon in the center, and shows the probability of detection

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[6]consistent with the statistical procedure described by Lunney (2).

[7]Except that, when the subject responded "Couldn't tell" to the target identification question, he was automatically assigned a related confidence score of zero (thus avoiding the statistically tricky processing of "I'm sure I don't know").

[8]by fitting a normal curve to the number of correct identifications of tracer at each OP.

TABLE 2

Main Effects and Significant First-Order Interactions from Analyses of Variance of Four Dependent Variables in Day and Night Tests of Subject Group I

SOURCE		Error In Ammunition Identification			Confidence In Ammunition Identification			Error in Target Identification			Confidence In Target Identification		
		df	ms	F	df	ms	F	df	ms	F	df	ms	F
Between Subjects													
Main Effects													
Within Subjects													
Main Effects													
Light Level	(L)	1	6.6	40.44***	1	27.8	4.60	1	0.1	0.02	1	0.8	0.34
Error (L)		9	0.2		9	6.0		9	3.3		9	2.4	
Offset	(O)	4	2.2	15.85***	4	0.2	0.27	4	65.9	81.28***	4	103.1	68.84***
Error (O)		36	0.1		36	0.8		36	0.8		36	1.5	
Height	(H)	1	0.0	0.40	1	0.2	0.59	1	2.1	1.56	1	5.1	3.95
Error (H)		9	0.0		9	0.4		9	1.4		9	1.7	
Ammunition	(A)	7	28.3	873.26***	7	0.5	2.50*	7	64.2	74.70***	7	128.7	103.00***
Error (A)		63	0.0		63	0.2		63	0.9		63	1.2	
Significant 1st-Order Interactions													
(L) x (O)		4	2.3	17.06***				4	33.9	30.91***	4	53.2	38.58***
(L) x (A)		7	5.9	164.48***				7	45.1	56.29***	7	72.5	53.14***
(O) x (A)		28	0.2	2.98***				28	1.9	2.73***	28	3.1	2.83***

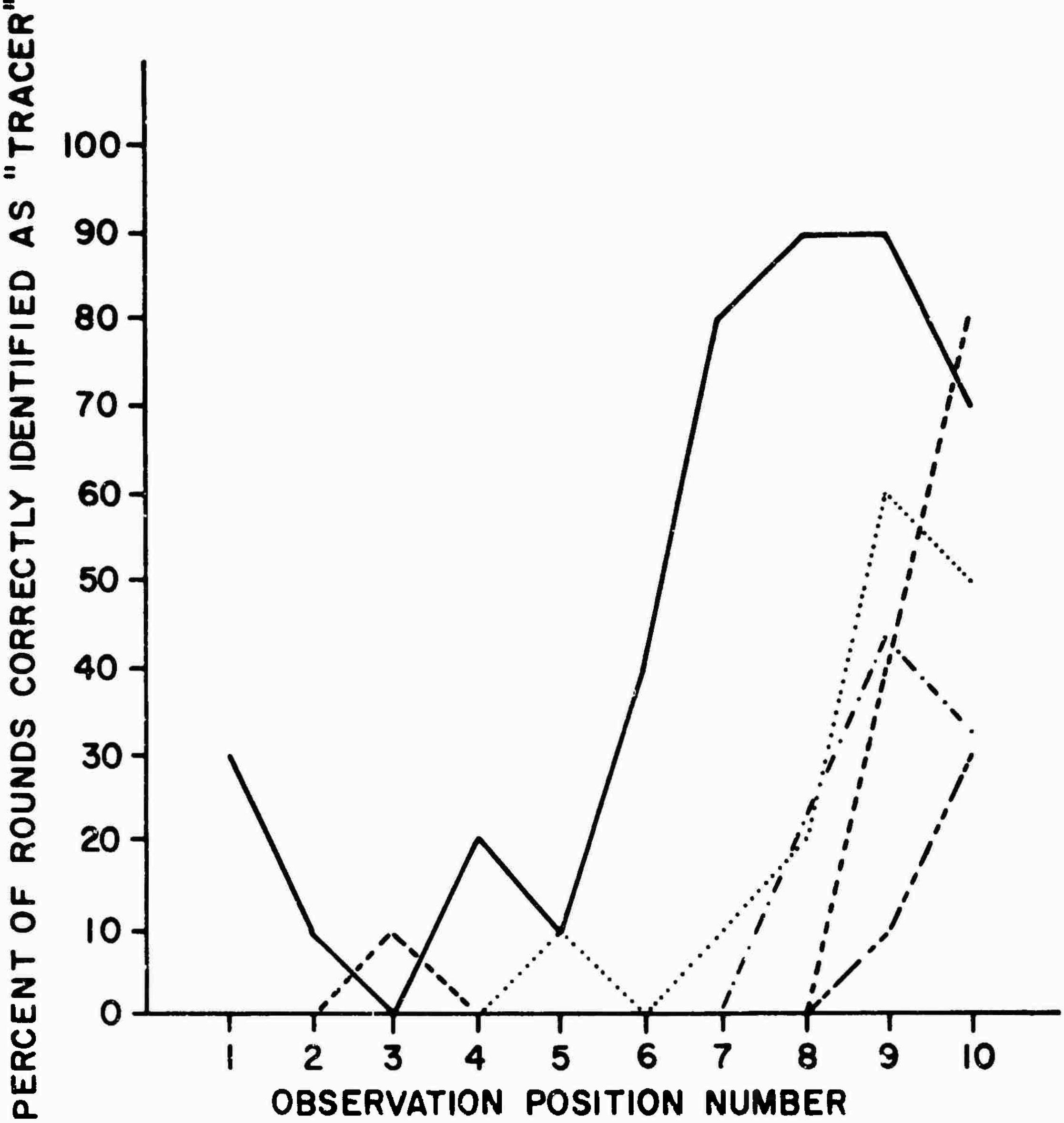
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

TABLE 3

Main Effects and Significant First-Order Interactions from Analyses of Variance of Four Dependent Variables in Daylight Tests of Subject Groups 1 and 2

SOURCE		Error in Ammunition Identification			Confidence In Ammunition Identification			Error In Target Identification			Confidence In Target Identification		
		df	ms	F	df	ms	F	df	ms	F	df	ms	F
Between Subjects													
Main Effects													
Group No.	(G)	1	18.1	61.17***	1	101.0	2.76	1	30.8	6.12*	1	87.4	9.97**
Error (b)		18	0.3		18	36.6		18	5.0		18	8.8	
Within Subjects													
Main Effects													
Offset	(O)	4	12.2	69.45***	4	9.7	4.74**	4	183.5	174.53***	4	305.8	171.14***
Error (O)		72	0.2		72	2.1		72	1.1		72	1.8	
Height	(H)	1	0.4	9.81**	1	0.2	0.40	1	8.1	7.84*	1	13.7	10.28**
Error (H)		18	0.0		18	0.5		18	1.0		18	1.3	
Ammunition	(A)	7	20.3	289.11***	7	7.5	8.62***	7	49.5	81.36***	7	97.1	95.56***
Error (A)		126	0.1		126	0.9		126	0.6		126	1.0	
Significant 1st-Order Interactions													
(G) x (A)		7	2.7	38.84***	7	6.5	7.43***				7	46.8	46.08***
(O) x (H)		4	0.2	3.29*									
(O) x (A)		28	0.6	9.12***				28	4.6	5.75***	28	7.2	5.70***
(G) x (H)		1	0.2	4.70*									
(G) x (O)					4	13.3	6.49***						

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$



LEGEND

——— 7.62 mm. TRACER M62

------ 5.56 mm. TRACER M196

·············· 7.62 mm. SUPER-HEAVY KOTAGUN RED

-·-·-·- COMPOSITE OF 3 TYPES OF 7.62 mm. EXTRA-HEAVY KOTAGUN

--·-—·· 5.56 mm. EXTRA-HEAVY KOTAGUN RED

Figure 5. Correct detections of tracer in daylight of subject group 1 by ammunition type and observation position.

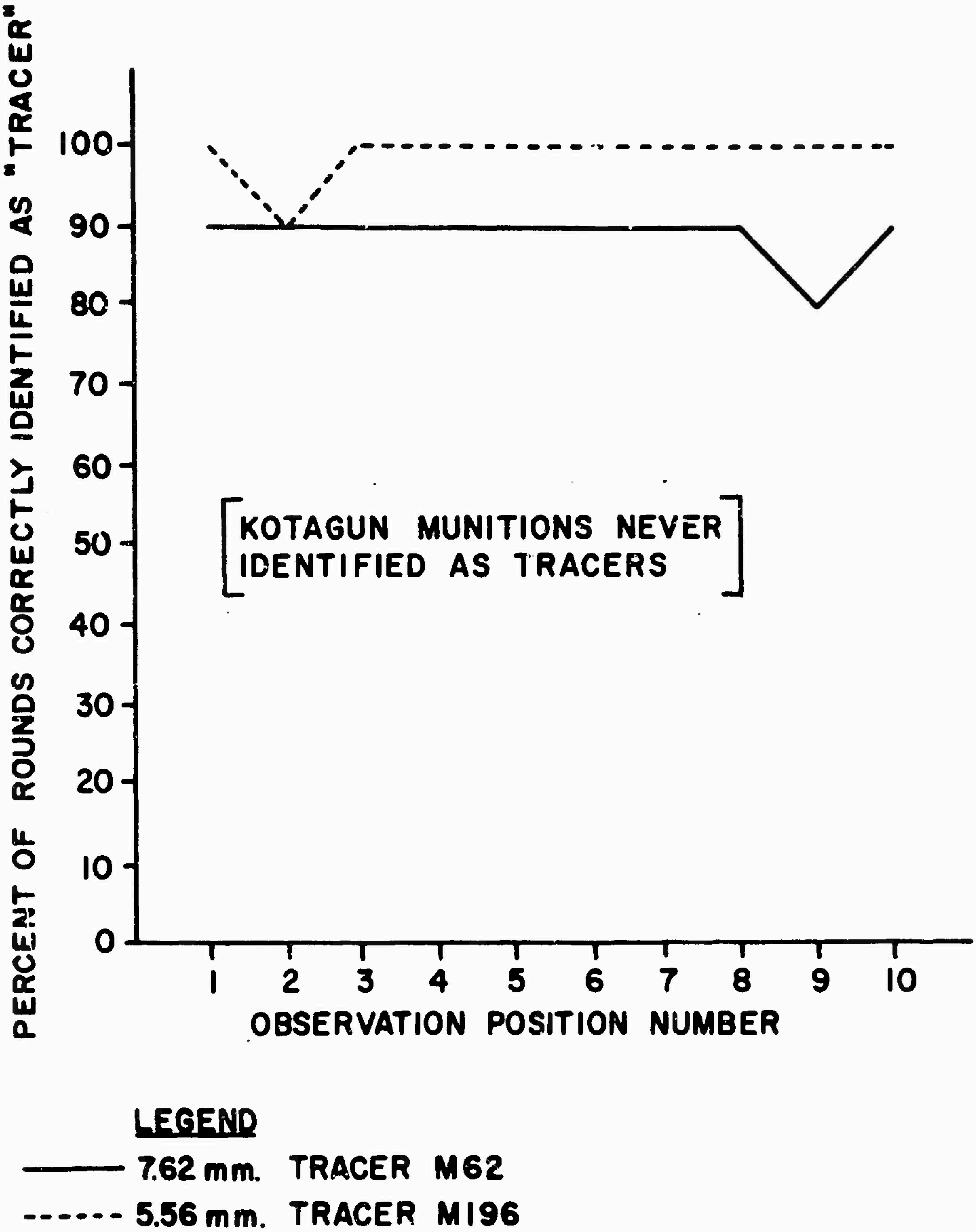


Figure 6. Correct detection of tracer at night of subject group 1 by ammunition type and observation position.

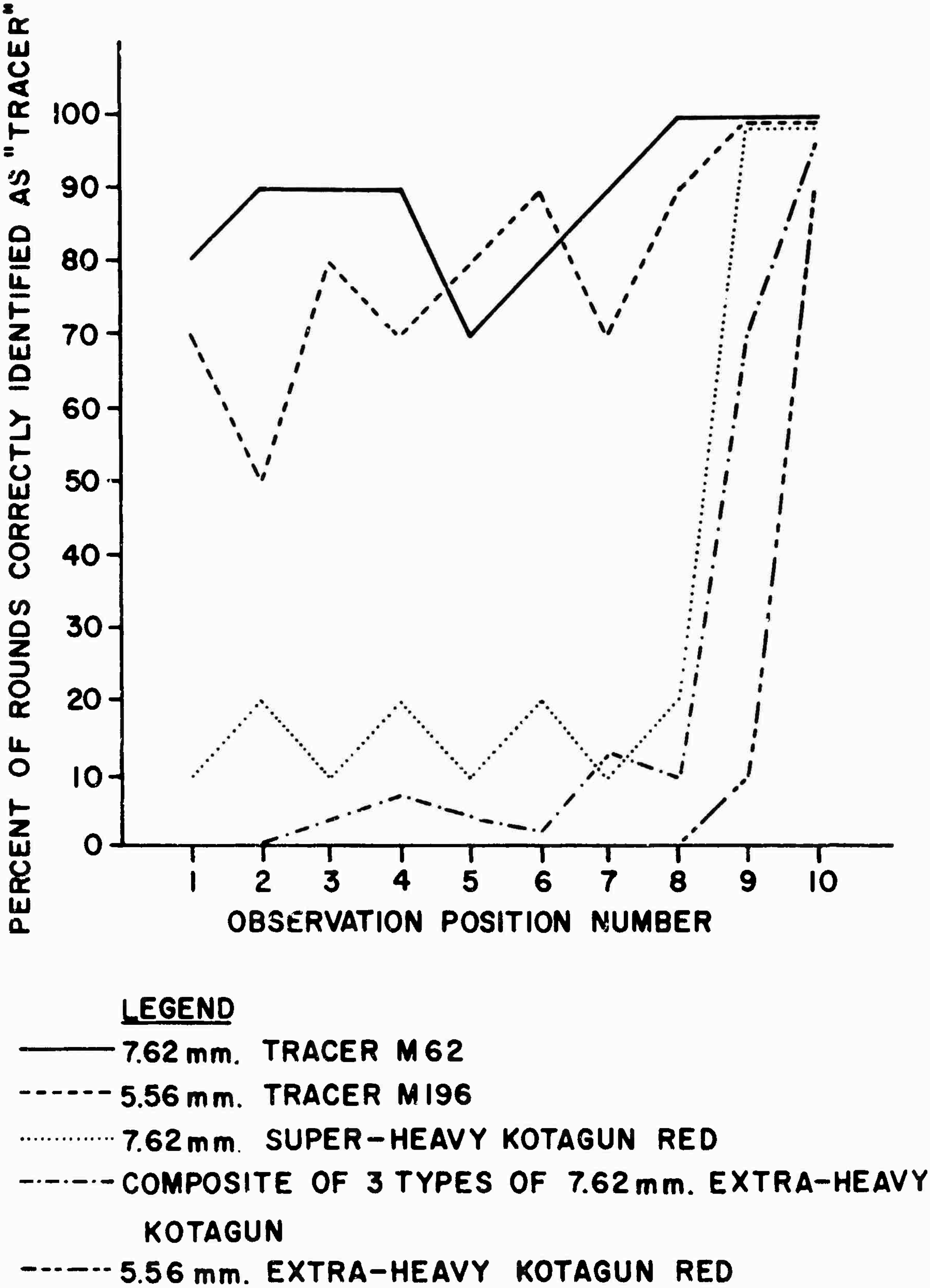


Figure 7. Correct detections of tracer in daylight of subject group 2 by ammunition type and observation position.

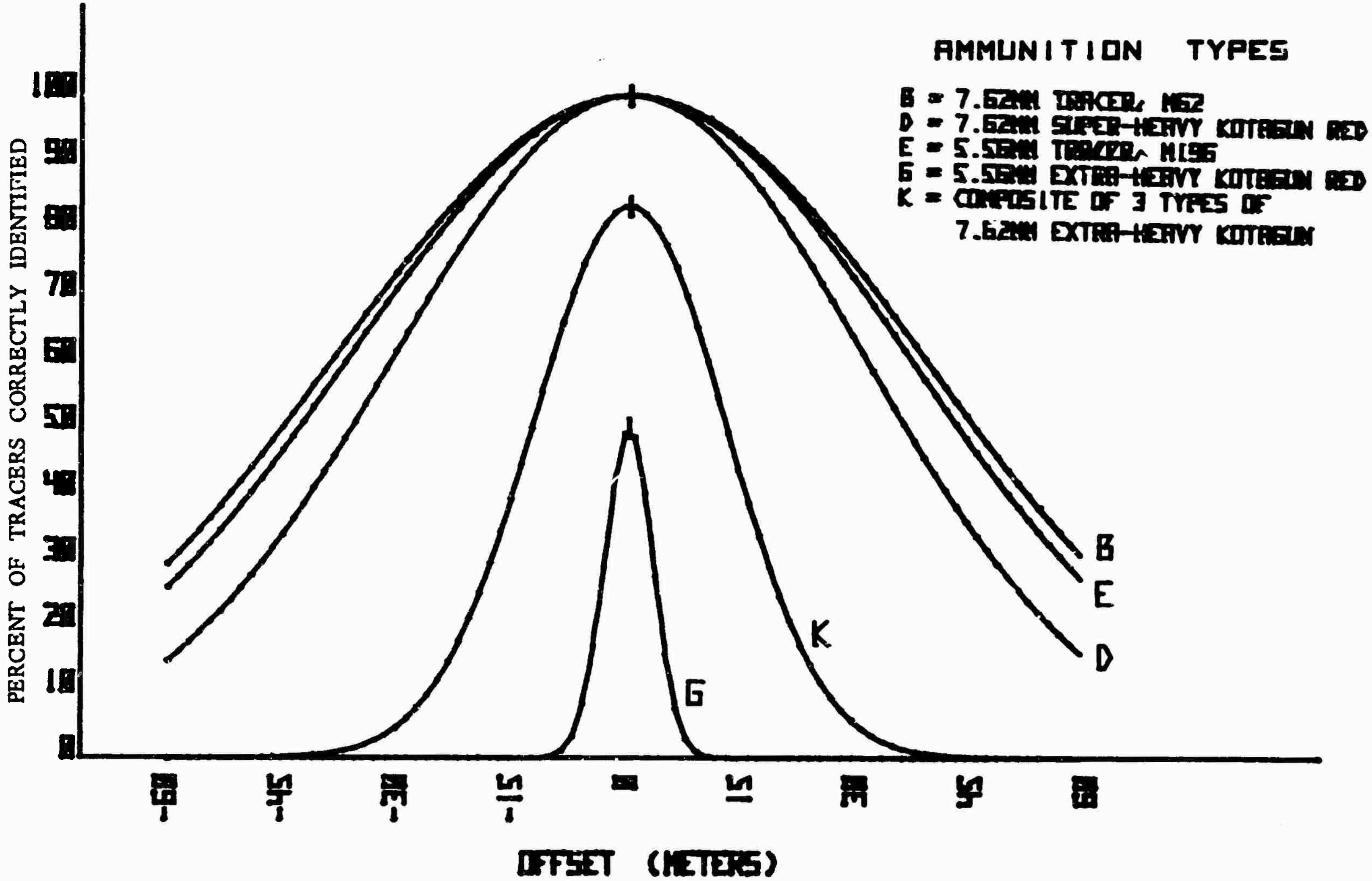


Figure 8. Normalized distributions of correct detections of tracer in daylight by offset and ammunition type for subject group 2.

of the different types of tracer as a function of the observer's place in the squad. As shown in Figure 8, pyrotechnic tracer was consistently detected more frequently than the Kotagun munitions.

– The superior detectability of pyrotechnic tracer increased with the observer's offset from the weapon firing.

– The 5.56mm Extra-Heavy Kotagun Red tracer was detected only from the positions directly behind the weapon firing.

Confidence in Ammunition Identification

Summaries (M, S.D., N) of subjects' "confidence in ammunition identification" responses are shown in Tables 4 through 6 by height, ammunition type and OP number.

The mean confidence score for Group 1 in daylignt was 4.62 (S.D. = .708, N = 800) and at night was 4.88 (S.D. = .366, N = 800). The mean difference was not statistically significant in the analysis of variance (Table 2), and there were no significant interactions. The only difference in subjects' responses to this question was as a function of ammunition type ($p < .05$), and the difference is primarily noticeable in the much smaller standard deviations at night.

The mean confidence score for Group 2 in daylight was 4.11 (S.D. = 1.274, N = 800). It did not differ significantly in the analysis of variance (Table 3) from the mean score for Group 1 in daylight; however, Group 2's confidence scores were significantly affected in that analysis by both offset and ammunition type. Confidence in ammunition identification decreased as the observer became increasingly offset from the weapon firing and was higher with the pyrotechnic tracers than with the Kotagun munitions.

Target Identification

The percentages of targets correctly identified are shown as a function of observation position and ammunition type in Figures 9 through 11. There are certain similarities to the data in Figures 5 through 7 (Ammunition Identification) which are immediately apparent:

– Target identification is more accurate with pyrotechnic tracer.

– Accuracy in target identification decreases as the observer becomes increasingly offset from the firing weapon.

– Of the Kotagun munitions, Super-Heavy Kotagun Red consistently provided the most accurate target detections.

– The difference in accuracy of target identification between pyrotechnic tracer and the Kotagun munitions is the greatest at night.[9]

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[9] There is an apparent inconsistency between the data in Figures 6 and 10: if at night no subjects saw Kotagun tracer, how could they use it to detect targets? Because four alternative responses were offered to the target identification question (Fig. 4), any percent below 25 can represent a chance occurrence; and the lower part of Figure 10 is essentially noise.

TABLE 4

Means and Standard Deviations of Confidence in Ammunition Identification Responses of Subject Group I in Daylight

Ammo Type		O All	F 0	F 15	S 30	E 45	T 60
A	Mean	4.66	4.80	4.65	4.50	4.75	4.60
	S.D.	.67	.52	.81	.83	.44	.68
B	Mean	4.73	4.90	4.95	4.70	4.55	4.55
	S.D.	.63	.45	.22	.73	.69	.83
C	Mean	4.63	4.50	4.60	4.75	4.70	4.60
	S.D.	.66	.89	.60	.55	.57	.68
D	Mean	4.64	4.55	4.55	4.75	4.57	4.79
	S.D.	.69	.83	.76	.44	.87	.42
E	Mean	4.53	4.45	4.50	4.60	4.65	4.45
	S.D.	.81	.89	.89	.75	.67	.89
F	Mean	4.57	4.30	4.70	4.65	4.60	4.60
	S.D.	.70	.87	.66	.67	.68	.60
G	Mean	4.57	4.50	4.60	4.55	4.65	4.55
	S.D.	.76	.83	.75	.83	.59	.83
H	Mean	4.59	4.45	4.60	4.65	4.70	4.55
	S.D.	.74	.89	.88	.59	.47	.83
	N =	100	20	20	20	20	20

LEGEND

A - 7.62mm Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange

TABLE 5

Means and Standard Deviations of Confidence in Ammunition Identification Responses of Subject Group I at Night

Ammo Type		O All	F 0	F 15	S 30	E 45	T 60
A	Mean	4.88	4.90	4.85	4.90	4.85	4.90
	S.D.	.33	.31	.37	.31	.37	.31
B	Mean	4.97	5.00	5.00	5.00	4.95	4.90
	S.D.	.17	-	-	-	.22	.31
C	Mean	4.86	4.75	4.95	4.90	4.85	4.85
	S.D.	.38	.55	.22	.31	.37	.37
D	Mean	4.87	4.90	4.90	4.90	4.80	4.85
	S.D.	.37	.31	.31	.31	.52	.37
E	Mean	4.89	5.00	4.95	4.75	4.90	4.85
	S.D.	.42	-	.22	.64	.45	.49
F	Mean	4.87	4.90	4.95	4.85	4.80	4.85
	S.D.	.37	.31	.22	.49	.41	.37
G	Mean	4.83	4.70	4.85	4.80	4.85	4.95
	S.D.	.47	.73	.37	.52	.37	.22
H	Mean	4.86	4.80	4.90	4.85	4.90	4.85
	S.D.	.35	.41	.31	.37	.31	.37
	N =	100	20	20	20	20	20

LEGEND

A - 7.62mm Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange

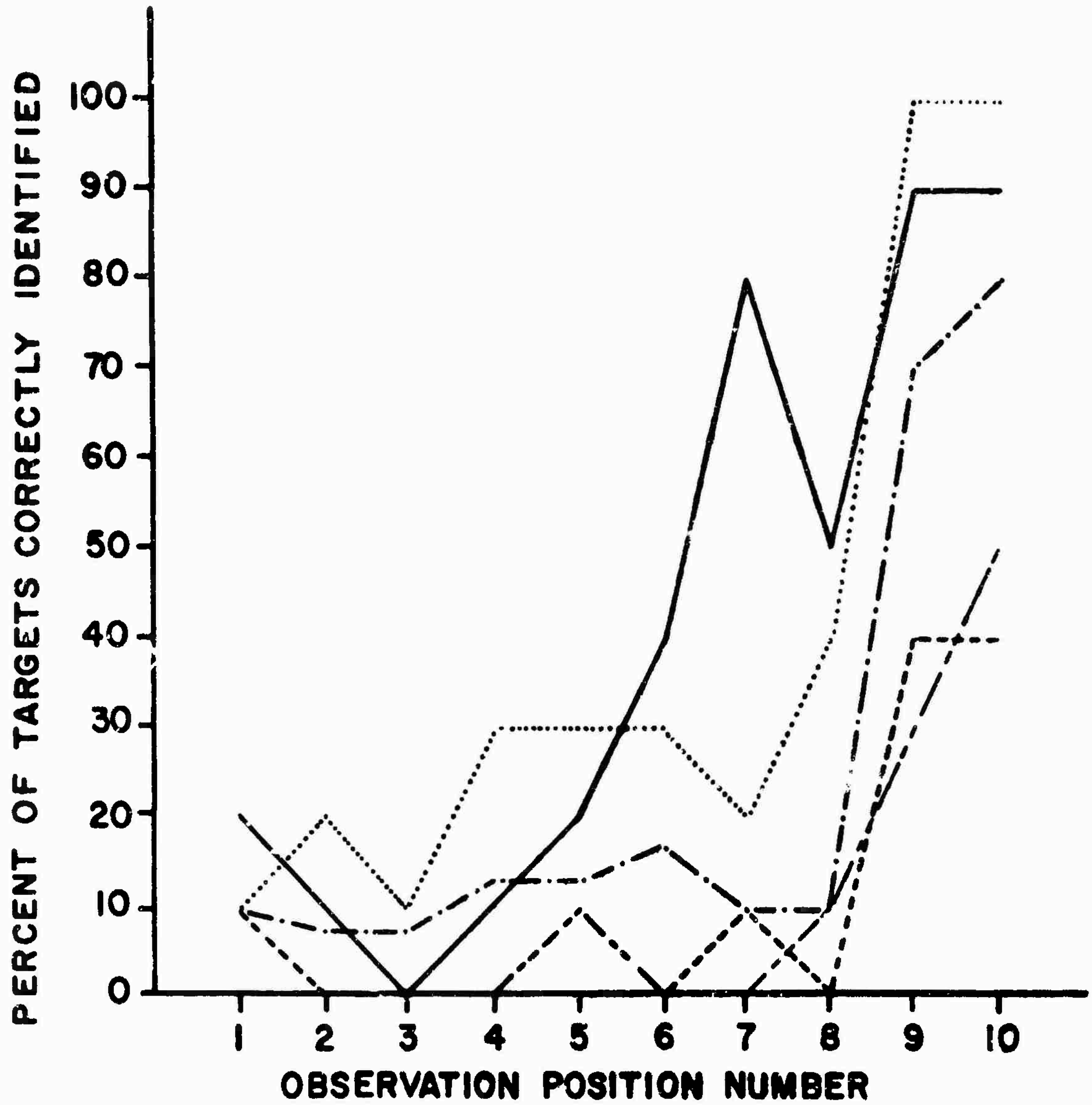
TABLE 6

Means and Standard Deviations of Confidence in Ammunition Identification Responses of Subject Group 2 in Daylight

		O	F	F	S	E	T
Ammo. Type		All	0	15	30	45	60
A	Mean	3.81	4.40	3.45	3.95	3.60	3.65
	S.D.	1.40	1.10	1.70	1.19	1.50	1.35
B	Mean	4.78	5.00	4.70	4.70	4.80	4.70
	S.D.	.73	-	.80	.66	.89	.92
C	Mean	3.92	4.75	3.90	3.65	3.80	3.50
	S.D.	1.29	.55	1.25	1.46	1.32	1.36
D	Mean	4.01	4.80	3.55	4.00	3.90	3.80
	S.D.	1.31	.62	1.57	1.34	1.29	1.28
E	Mean	4.62	5.00	4.30	4.85	4.55	4.40
	S.D.	.94	-	1.34	.67	.89	1.10
F	Mean	3.96	4.90	3.75	3.85	3.65	3.65
	S.D.	1.36	.45	1.29	1.42	1.53	1.50
G	Mean	3.90	4.55	3.90	3.85	3.60	3.60
	S.D.	1.36	.95	1.25	1.50	1.43	1.50
H	Mean	3.90	4.75	3.60	3.95	3.40	3.80
	S.D.	1.31	.55	1.43	1.32	1.57	1.11
	N =	100	20	20	20	20	20

LEGEND

A - 7.6[illegible]m Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange



LEGEND

——— 7.62 mm. TRACER M62

- - - - - 5.56 mm. TRACER M196

.... 7.62 mm. SUPER-HEAVY KOTAGUN RED

-·-·- COMPOSITE OF 3 TYPES OF 7.62 mm. EXTRA-HEAVY KOTAGUN

- - —— 5.56 mm. EXTRA-HEAVY KOTAGUN RED

Figure 9. Correct target identifications in daylight of subject group 1 by ammunition type and observation position.

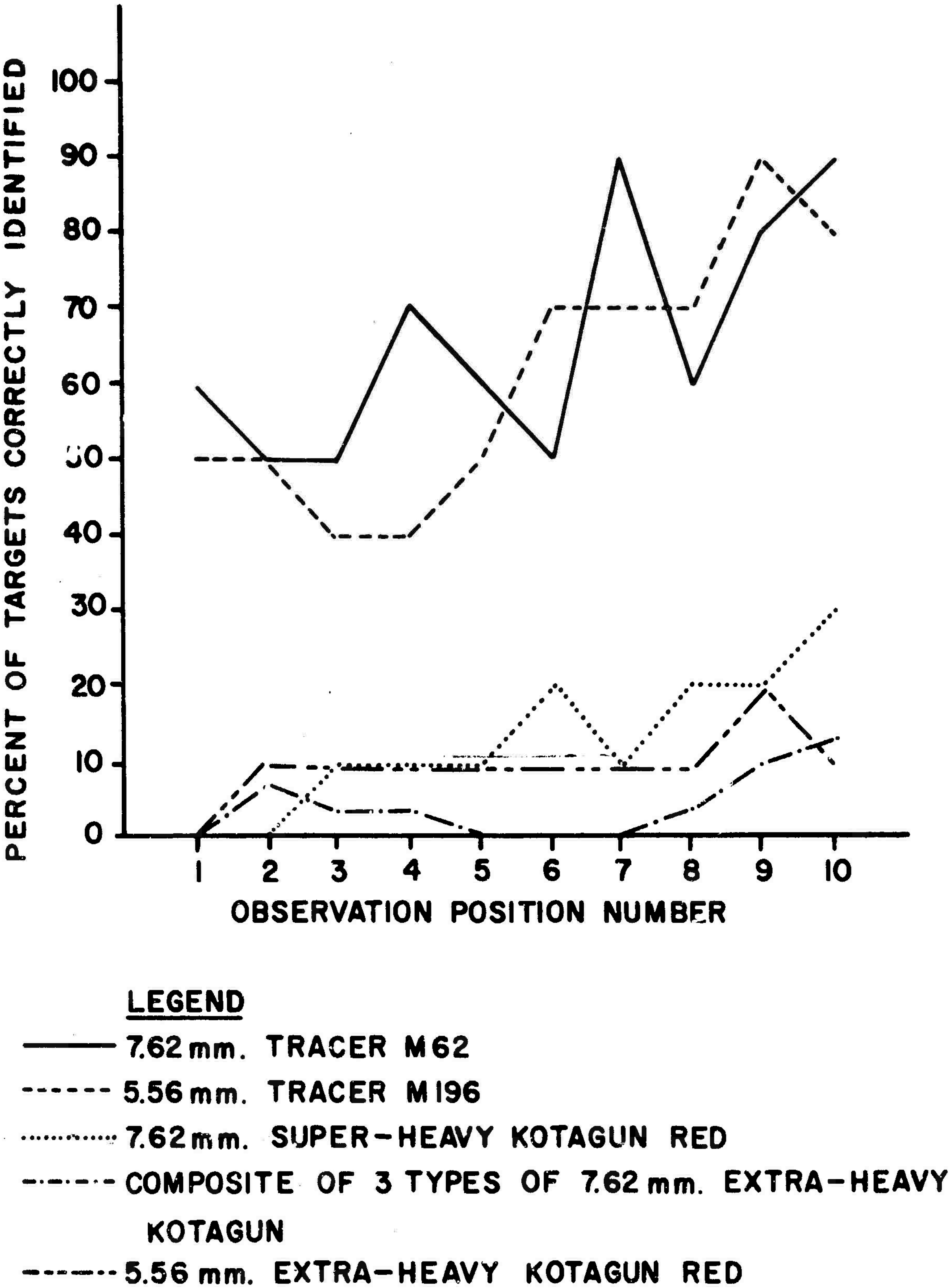
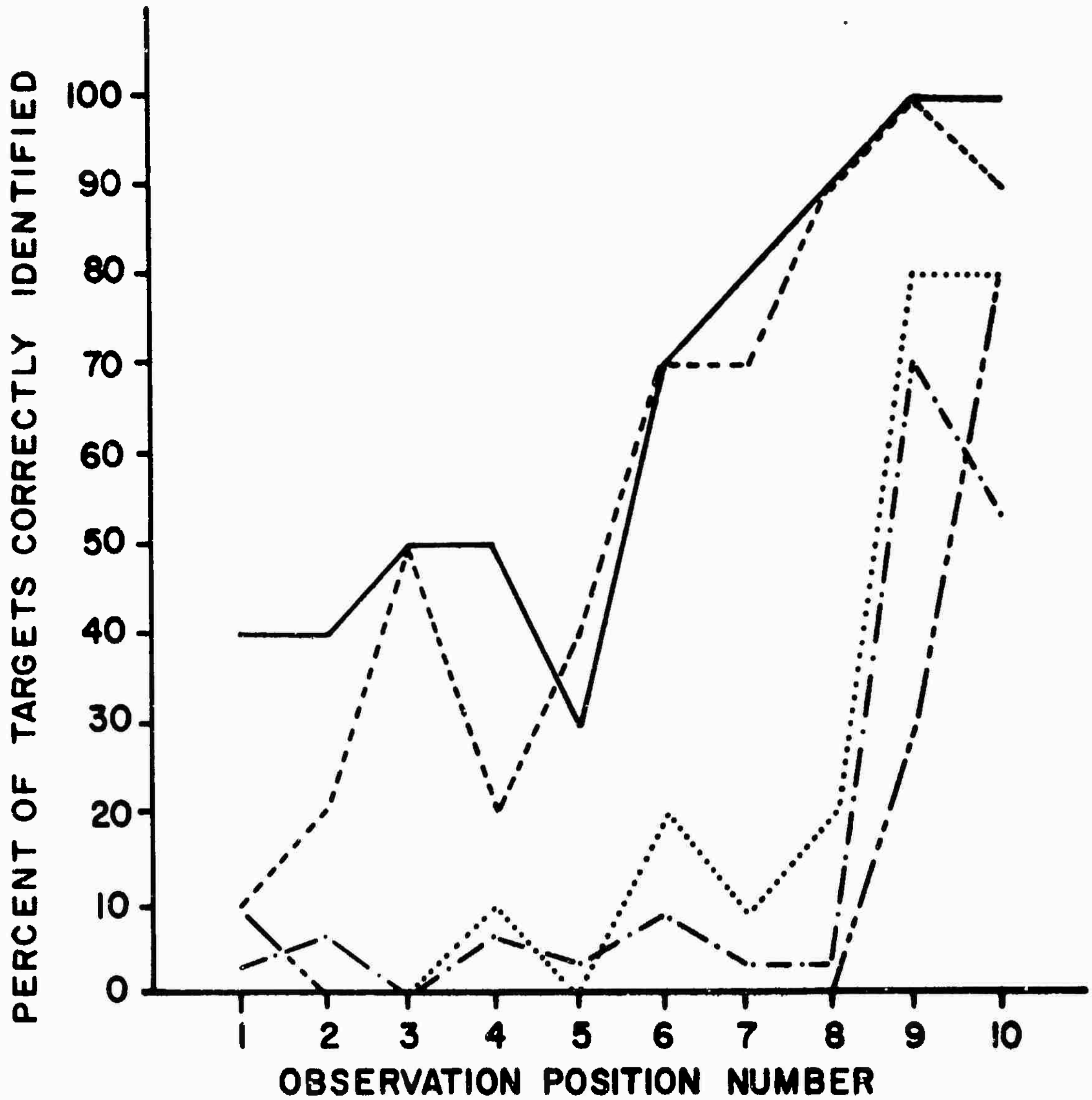


Figure 10. Correct target identifications at night of subject group 1 by ammunition type and observation position.



LEGEND

——— 7.62 mm. TRACER M62

------ 5.56 mm. TRACER M196

.... 7.62 mm. SUPER-HEAVY KOTAGUN RED

-·-·-·- COMPOSITE OF 3 TYPES OF 7.62 mm. EXTRA-HEAVY KOTAGUN

--—-- 5.56 mm. EXTRA-HEAVY KOTAGUN RED

Figure 11. Correct target identifications in daylight of subject group 2 by ammunition type and observation position.

Because of the existence of this fourth alternative ("Couldn't tell"), it becomes important to distinguish between actual errors in target identification (in which the subject drew an incorrect conclusion from his visual perception) and negative responses (in which the subject's visual perception was inadequate to support a conclusion). Of the 2,400 target identification responses, 1,646 were "Couldn't tell." Table 7 shows the percentage of this response as a function of subject group, light level, offset and ammunition type. This table shown that subjects perceived at least enough of a visual stimulus to make a judgment significantly more often with pyrotechnic tracer than with the Kotagun munitions. Of the remaining 754 responses, 570 (nearly 76%) were correct target identifications. Analysis of these responses (Table 8) shows subjects far more willing to make judgments when pyrotechnic tracer is fired and, except at night, when they are nearer to the weapon firing. Their accuracy parallels their willingness.

Confidence in Target Identification

Summaries (M, S.D., N) of subjects' "confidence in target identification" responses are shown in Tables 9 through 11 by offset and ammunition type. Because of the many significant first-order interactions (Tables 2 and 3) in these data, their complete analysis would be a lengthy (though perhaps academically interesting) exercise. However, the practical significance of this dependent variable is the answer to the question, "How accurate were the observers in judging their own performance?"

The answer to this question is shown graphically in Figure 12 by subject group and light level. There, only those confidence responses are included which were preceded by an actual (right or wrong) target identification; where subjects responded "couldn't tell" to question 3 (Figure 4), their confidence score was omitted from these graphs. Because of the large number of "couldn't tell" responses (Table 7), it is important to interpret the mean confidence scores shown on the left of Figure 12 in consonance with the sample sizes on which they were based (shown on the right of Figure 12).

Among the more salient relationships shown there are:

– In daylight, subjects made 115 percent more target identifications with pyrotechnic tracer[10] (ammunition types B and E in Figure 13) than with the Kotagun munitions[11] (ammunition types C, D, F, G and H).

– For Group 1 (naive) in daylight the difference in the mean confidence scores between the correct and incorrect target identifications for pyrotechnic tracer was .59; for the Kotagun munitions, that difference increased to 1.54.

– For Group 2 (which was given training in the detection of the Kotagun "tracer") those differences were .32 and .76 respectively (albeit under somewhat different daylight conditions).

[10] 230 identifications out of 400 opportunities

[11] 259 identifications out of 1000 opportunities

TABLE 7

Percent of "Couldn't Tell" Responses to Target Identification Question by Ammunition Type

Group No.	Light Level	Offset (meters)	A	B	C	D	E	F	G	H	N Size
			AMMUNITION TYPE								
1	Day		93	10	91	84	18	92	88	93	100
	Night		81	13	72	67	20	79	87	74	100
2	Day		85	52	73	58	85	75	89	67	100
1	Day	0	60	0	20	0	40	15	55	10	20
		15	100	15	90	70	95	95	95	85	20
		30	90	70	90	70	100	80	95	75	20
		45	90	95	85	80	95	90	100	85	20
		60	85	80	80	70	95	95	100	80	20
	Night	0	90	10	80	75	5	90	75	90	20
		15	95	10	90	85	10	90	90	90	20
		30	100	10	100	85	20	95	90	95	20
		45	90	10	90	85	35	95	90	90	20
		60	90	10	95	90	20	90	95	95	20
2	Day	0	13	0	15	10	0	10	40	10	20
		15	95	15	85	80	20	100	100	90	20
		30	80	20	95	85	15	90	100	85	20
		45	95	10	80	85	25	100	100	100	20
		60	70	20	85	75	40	95	95	85	20

LEGEND

A - 7.62mm Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange

TABLE 8

Frequency of Correct Target Identifications Given A Target Was Identified
(N = 754)

Group No.	Light Level	Offset (meters)		AMMUNITION TYPE A	B	C	D	E	F	G	H
1	Day		Occurrence	11/15	41/48	21/27	39/42	10/15	22/25	10/11	28/33
			Percent	73	85	78	93	67	88	91	85
	Night		Occurrence	4/7	66/90	6/9	13/16	61/82	3/8	10/12	3/7
			Percent	57	73	67	81	74	38	83	43
2	Day		Occurrence	9/19	65/87	21/28	22/33	56/80	16/21	12/13	21/26
			Percent	47	75	75	67	70	76	92	81
1	Day	0	Occurrence	6/8	18/20	13/16	20/20	8/12	16/17	8/9	16/18
			Percent	75	90	81	100	67	94	89	89
		15	Occurrence	0/0	13/17	2/2	6/6	1/1	1/1	1/1	3/3
			Percent	0	77	100	100	100	100	100	100
		30	Occurrence	2/2	6/6	2/2	6/6	0/0	3/4	1/1	4/5
			Percent	100	100	100	100	100	75	100	80
		45	Occurrence	2/2	1/1	2/3	4/5	0/1	2/2	0/0	2/3
			Percent	100	100	67	80	0	100	0	67
		60	Occurrence	1/3	3/4	2/4	3/5	1/1	0/1	0/0	3/4
			Percent	33	75	50	60	100	0	0	75
	Night	0	Occurrence	0/2	17/18	3/4	5/5	17/19	2/2	3/5	2/2
			Percent	0	94	75	100	90	100	60	100
		15	Occurrence	1/1	15/18	0/2	3/3	14/18	1/2	2/2	0/1
			Percent	100	83	0	100	78	50	100	0
		30	Occurrence	0/0	11/18	0/0	3/3	12/16	0/1	2/2	0/1
			Percent	0	61	0	100	75	0	100	0
		45	Occurrence	2/2	12/18	2/2	2/3	8/13	0/1	2/2	0/2
			Percent	100	67	100	67	62	0	100	0
		60	Occurrence	1/2	11/18	1/1	0/2	10/16	0/2	1/1	1/1
			Percent	50	61	100	0	63	0	100	100
2	Day	0	Occurrence	4/7	20/20	15/17	16/18	19/20	16/18	11/12	16/18
			Percent	57	100	88	89	95	89	92	89
		15	Occurrence	1/1	17/17	1/3	3/4	16/16	0/0	0/0	1/2
			Percent	100	100	33	75	100	0	0	50
		30	Occurrence	1/4	10/16	1/1	2/3	11/17	0/2	0/0	3/3
			Percent	25	63	100	67	65	0	0	100
		45	Occurrence	0/1	10/18	2/4	1/3	7/15	0/0	0/0	0/0
			Percent	0	56	50	33	47	0	0	0
		60	Occurrence	3/6	8/16	2/3	0/5	3/12	0/1	1/1	1/3
			Percent	50	50	67	0	25	0	100	33

LEGEND

A - 7.62mm Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange

TABLE 9

Means and Standard Deviations of Confidence in Target Identification Responses of Subject Group 1 in Daylight

Ammo. Type		O All	F 0	F 15	S 30	E 45	T 60
A	Mean	1.37	2.10	1.00	1.20	1.40	1.15
	S.D.	.99	1.52	-	.62	1.23	.37
B	Mean	2.76	4.70	4.25	2.10	1.20	1.55
	S.D.	1.91	.80	1.48	1.74	.89	1.23
C	Mean	1.84	3.75	1.35	1.25	1.35	1.50
	S.D.	1.52	1.62	1.09	.91	.99	1.24
D	Mean	2.42	4.60	2.10	1.80	1.76	1.84
	S.D.	1.79	.82	1.74	1.40	1.51	1.57
E	Mean	1.49	3.25	1.10	1.00	1.05	1.05
	S.D.	1.25	1.94	.45	-	.22	.22
F	Mean	1.81	4.00	1.10	1.45	1.40	1.10
	S.D.	1.50	1.52	.45	1.05	1.23	.45
G	Mean	1.35	2.50	1.20	1.05	1.00	1.00
	S.D.	1.08	1.85	.89	.22	-	-
H	Mean	2.06	4.00	1.50	1.60	1.55	1.65
	S.D.	1.62	1.34	1.24	1.27	1.36	1.39
	N =	1.00	20	20	20	20	20

LEGEND

A - 7.62mm Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange

TABLE 10

Means and Standard Deviations of Confidence in Target Identification Responses of Subject Group 1 at Night

		O	F	F	S	E	T
Ammo. Type		All	0	15	30	45	60
A	Mean	1.14	1.25	1.10	1.00	1.20	1.15
	S.D.	.53	.79	.45	-	.62	.49
B	Mean	4.39	4.60	4.35	4.40	4.40	4.20
	S.D.	1.26	1.23	1.35	1.27	1.27	1.28
C	Mean	1.13	1.35	1.10	1.00	1.15	1.05
	S.D.	.46	.81	.31	-	.49	.22
D	Mean	1.56	1.85	1.40	1.60	1.60	1.35
	S.D.	1.35	1.63	1.10	1.47	1.47	1.09
E	Mean	3.70	4.60	4.05	3.40	3.20	3.25
	S.D.	1.56	1.00	1.32	1.67	1.77	1.59
F	Mean	1.13	1.20	1.15	1.10	1.05	1.15
	S.D.	.46	.62	.49	.45	.22	.49
G	Mean	1.28	1.60	1.15	1.25	1.20	1.20
	S.D.	.85	1.19	.49	.91	.62	.89
H	Mean	1.13	1.25	1.05	1.10	1.15	1.10
	S.D.	.54	.91	.22	.45	.49	.45
	N =	100	20	20	20	20	20

LEGEND

A - 7.62mm Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange

TABLE 11

Means and Standard Deviations of Confidence in Target Identification Responses of Subject Group 2 in Daylight

Ammo.		O	F	F	S	E	T
Type		All	0	15	30	45	60
A	Mean	1.62	2.35	1.20	1.50	1.20	1.85
	S.D.	1.36	1.90	.89	1.15	.89	1.46
B	Mean	4.24	5.00	4.25	4.00	4.25	3.70
	S.D.	1.39	-	1.45	1.62	1.37	1.56
C	Mean	1.89	4.25	1.30	1.15	1.50	1.25
	S.D.	1.53	1.48	.73	.67	1.10	.64
D	Mean	2.14	4.45	1.60	1.50	1.45	1.70
	S.D.	1.70	1.28	1.31	1.24	1.15	1.34
E	Mean	3.92	5.00	4.10	4.05	3.55	2.90
	S.D.	1.63	-	1.65	1.61	1.70	1.77
F	Mean	1.78	4.50	1.00	1.25	1.00	1.15
	S.D.	1.55	1.24	-	.91	-	.67
G	Mean	1.43	3.10	1.00	1.00	1.00	1.05
	S.D.	1.17	1.83	-	-	-	.22
H	Mean	1.82	4.25	1.15	1.40	1.00	1.30
	S.D.	1.49	1.29	.49	1.00	-	.92
	N =	100	20	20	20	20	20

LEGEND

A - 7.62mm Ball, M80
B - 7.62mm Tracer, M62
C - 7.62mm Extra-heavy Kotagun Red
D - 7.62mm Super-heavy Kotagun Red
E - 5.56mm Tracer, M196
F - 7.62mm Extra-heavy Kotagun White
G - 5.56mm Extra-heavy Kotagun Red
H - 7.62mm Extra-heavy Kotagun Orange

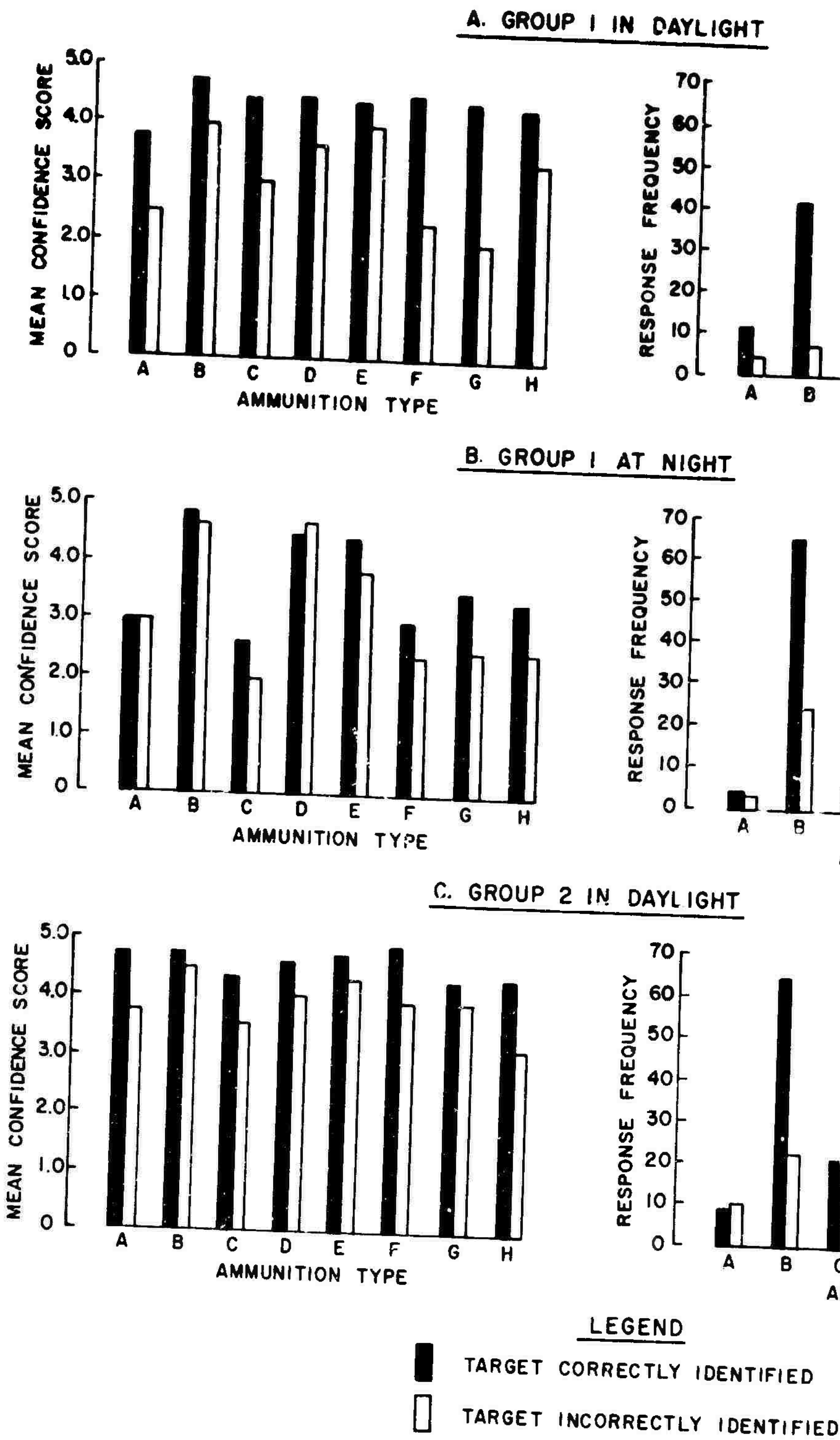


Figure 12. Means and sample sizes of confidence in target identification by group and ammunition type

Weapon Malfunctions

The weapons in the machine tests malfunctioned approximately 10 percent of the time. In each case, a Kotagun munition had failed to chamber. Super-Heavy Kotagun Red was the ammunition most frequently involved.

DISCUSSION

General

There are a number of purposes and uses postulated for tracer ammunition besides that of aiding a single gunner adjusting fire on a given target (4, p. B-2). However, all of these roles have at least one point in common: the tracer must be detected by one or more observers before they can draw the necessary conclusions or initiate the appropriate action. Therefore, a knowledge of the "detectability" of any particular type of tracer (as a function of the environment and circumstances of the observer) provides the fundamental baseline data for predictions of the utility of tracer in a particular role.

In this test, the observers had no other tasks than to observe the trace phenomena and to record their judgments of them. In addition, they were given an alerting command just prior to the firing of each round, and their observations were made on a structured range devoid of the ambiguities which often characterize a combat situation. These circumstances combine to maximize observer performance and, hence, may be interpreted as human performance ceiling for the tasks described.

As measured in this test, there are consistent differences between the detectability of pyrotechnic tracer and the Kotagun munitions. Standard, pyrotechnic tracer is far more detectable—even by observers trained in vapor trail detection—across a wider area, and it produces far more accuracy in determining ground locations. In addition, the "Super-Heavy Kotagun Red" munition (which was the most often correctly detected of the five types of vapor trail tracer) was associated with a large number of weapon malfunctions. In each case, the malfunction was identified as "failure to chamber" and was attributed to the thickness of the chemical coating on the projectile. While the technological feasibility of producing daylight vapor trail tracer seems to have been demonstrated, its military potential may be circumscribed if its visibility can be improved only by thicker projectile coatings which, in turn, cause stoppages.

Daylight Tracer Visibility

Two groups of subjects from the same military organization had substantially different responses on the same perceptual tasks in "daylight." There is, of course, ample evidence that individuals tend to differ on any performance measure. Moreover, the subjects in Group 2 received a different orientation to the test and, therefore, presumably had a "set" which would bias their performance in a higher direction. That their detection of vapor trail tracer was nearly twice that of subjects in Group 1 would normally be explainable in terms of this difference in training. However, an intervening (and, in this case, probably confounding) variable was also operating: the difference in light level (caused by an unexpected change in the weather). Although photometric readings were not taken during the daylight tests, the effect of the change in daylight level can probably be inferred from the difference in detection of M62 tracer between the two groups: 44 percent for Group 1 and 89 percent for Group 2. This striking difference highlights the crux of the daylight tracer visibility problem.

For at least the past decade, QMRs, SDRs, MNs and now ROCs[12] for new small arms have contained a requirement for "...a daylight tracer to the maximum effective range of the weapon." Such a requirement—at least from a developer's viewpoint—is meaningless without further clarification. There are many varieties of daylight seeing conditions (not all of which are distinguished by such physical measures as "brightness" or "ambient illumination"). Data gathered thus far in the HEL Tracer Program suggest that one of the principal factors which will control the "effectiveness" of tracer is the quality of the seeing conditions in which it is employed. It thus appears important as a first step in improving tracer technology to define the seeing conditions in which "daylight tracer" is supposed to be effective. It appears feasible to accomplish this step using the principles of visual task evaluation (explained by Martin in (3)). A second useful step would be to persuade the requirements originator to state what it is he wants the tracer to do; that is, perform what function(s) under what conditions. The existence of such a statement in a requirements document could provide the materiel developer not only a standard against which to test[13], but also clear direction of the tracer ammunition research and development program.

Miscellaneous

At the conclusion of the night test, when the subjects had departed and a group of observers from USASASA was puzzling over the difficulty in detecting vapor trail tracer (Figure 6), it was suggested that the Kotagun munitions might be more visible if fired from a hot weapon. Both an M14 rifle and an M16 rifle were "heated" by firing a 10-round magazine of standard ammunition on full automatic setting. Then Kotagun munitions were immediately fired from these weapons. No visible Kotagun tracers were reported by the observers. (Although, in the daylight tests, the same observers reported detecting vapor trails ranging in length from 50 to 300 meters, with a mean estimated range of 150 meters.)

The effect of offset[14] on detection and use of tracer (noted in (4)) appeared in these data also. However, the magnitude of the difference between pyrotechnic and vapor trail tracer substantially eliminates for the latter the signaling and communication roles postulated for tracer.

For several years, persons associated with the HEL Tracer Program have remarked on what seems to be a systematic peculiarity within the data: the divergence between objective performance measures of tracer in daylight and subjects' opinions as to its effectiveness. This phenomenon occurs again within these data. Correct detections of tracer varied widely as a function of ammunition type (Figures 5 and 7). Yet the mean confidence in these detections is quite high: 4.75 (S.D. = .54, N = 1600). The phenomenon is repeated in target identification, where (1) all subjects in daylight expressed nearly identical confidence in their right and wrong answers when pyrotechnic tracer was fired and (2) the group trained in detecting Kotagun "tracer" was less able to distinguish between correct and incorrect identifications with it than was the naive group. This discrepancy is interpreted as indicating soldiers believe that, if tracer <u>were</u> being fired, they would see it and use it accurately; the belief is erroneous. Prior to the conclusion of this research program it would seem important to account for this consistent discrepancy.

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[12]acronymns for materiel requirements documents

[13]The present insufficiency of tracer "testing" is discussed in (4, p. 91).

[14]see page 3 above

CONCLUSIONS

1. In daylight, vapor trail tracer can be detected and used by trained persons located behind the firing weapon to discriminate between ground locations 10 meters apart at a range of 400 meters.

2. Daylight detection and use of vapor trail tracer are affected by variations in ambient light and observer training; the nature of the interaction between these factors was not established.

3. The accuracy and reliability of this detection and use vary with the type of coating applied to the projectile.

4. In this test, accuracy and reliability of detection and use of vapor trial tracer were greatest when the projectile had the heaviest coating of the Kotagun composition. Projectiles with this heavy coating frequently would not chamber in the M14 rifle.

5. None of the Kotagun munitions used in this test left a vapor trail detectable at night.

6. The observer's location with respect to the weapon firing affects his detection and use of all types of tracer, with increase in proximity associated with increased accuracy.

7. The feasibility of Kotagun tracer for military use is not established for three principal reasons:

a. it is not visible at night.

b. Its detectability from positions adjacent to the firer's own is limited (thereby effectively precluding its use as a signal among squad members).

c. The most easily detectable Kotagun munition is also associated with a high rate of weapon failure.

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APPENDIX A

DESCRIPTION OF KOTAGUN MUNITIONS

The Kotagun munitions used in this test were made by applying a coating to projectiles of standard 7.62mm and 5.56mm ball ammunition. Each round was solution-coated nose-down by a dipping process so that the coating was applied to that portion of the projectile which protruded from the cartridge case as well as about 1/8th inch of the case mouth. In addition, the nose of each projectile was subjected to a second dip to provide a thicker coat—which would theoretically provide a longer trace.

The material named "Kotagun red" is an organic non-polymeric composition which is said to leave a white vapor trail in daylight and give off a dim yellow light at night. To increase the night visibility of this phenomenon, an orange and a white fluorescent compound were added to the basic Kotagun material, producing, respectively, Extra-Heavy Kotagun Orange and Extra-Heavy Kotagun White.

The munition described as Super-Heavy Kotagun Red was produced by applying a thicker coating of the Kotagun red material to the ammunition.[1]

Upon initial inspection at Aberdeen Proving Ground of the coated ammunition shipped by DuKote Corporation, it was found that, although the rounds of ammunition had been securely taped to heavy cardboard during shipment, the coating of many of the rounds had been chipped and cracked. This condition was noted on all 7.62mm munitions except Extra-Heavy Kotagun Red. During subsequent handling in the testing described in this report, additional chipping and flaking of the coatings were noted.

[1]The information presented above was provided to the U. S. Army Human Engineering Laboratory at the time the tests were conducted and was produced from a summary of oral presentations by Dr. John Bernath (DuKote Corp.) and written analyses by Charles N. Bernstein, a government chemist. HEL's participation in this program did not include either investigation into or verification of this information.

APPENDIX B

SUBJECT ORIENTATIONS

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ORIENTATION 1

You men are about to participate as observers in an observation test of tracer ammunition. A tracer—as you'll recall from your training—is a round of ammunition in which a cavity on the rear of the bullet has been filled with a chemical material which burns as the bullet flies through the air.

The U. S. Army has been making tracer ammunition since World War I. We've made a lot of different types. And we're continuing to experiment with new types. We have some to show you today. The purpose of this test is to find out how some of the different tracer compounds compare with one another on two important measures of performance: detection and use. In a moment, I'll discuss with you how we measure that performance and how we will conduct the test.

First, some words on safety: If you will look to your front, you will see the firing/observing line. It is located on that sand berm and marked by engineer tape. At no time move forward of that tape. I repeat: at no time move forward of the engineer tape. Second, the weapons on this range will be fired electrically from the control point, which is located over there (point). Consequently, there are cables carrying electricity in several places on this range. Throughout this test you will be required to move along the firing line. When you move, please walk; do not run. And when you walk, please watch where you're going. We have the electric cables marked, and we would like you to step over them, not fall over them. Also, you will each have a chance to mount our five observation towers. We would like you to climb up and climb down carefully. NO PLFs, please. Finally, will you stay out of the ammo point which is located to your rear, and will you please not smoke while you are on this range. In the event of a weapon malfunction or other unscheduled event, will you please remain at your OP and listen to the PA set for instructions. Are there any questions so far?

OK, then let me tell you about this test. First, each of you will receive a quick vision check in that area over there. If you normally wear spectacles or contact lenses, please have them on or in when you report for your visual acuity check.

After we've verified that you can see, we will ask you to move to an observation point along the line to your front. Notice that the points are numbered. Number 1 is on the left, number 10 on the right. The towers are the odd-numbered positions, the chairs are the even-numbered points. After you go to the designated OP, look around for the code letter associated with that point. It will be printed on a blue 3 x 5 card like this. When you find it, write that letter in the appropriate place in the observation booklet we will issue you.

Then we'll begin the test. On the PA set we will tell you what round number we are about to fire. You turn in your observation booklet to the page with that number on it. Then you will hear the command, "Observers, watch the range." At that time, look downrange. You will see three white E-type silhouette targets side by side at a range of 400 meters. Then you will hear a round fired. One round. It will be fired at one of the three targets downrange. It may be a round of tracer or it may be a round of ball ammunition. After you've watched it, look in your observation booklet. The page will look like this (show chart).

We'd like you to answer the four questions. The first one says, "Was the round tracer or ball?Circle one." If you saw tracer, draw a circle around the word "tracer." If you didn't see tracer, draw a circle around the word "ball." Question two asks how sure you are about that last answer. If you're sure the round was a tracer or if you're sure it was a ball round, draw a circle around the word "sure."If you think it was, but you're not sure, draw a circle around "think so." There are five possible answers to this question. Pick just one, and draw a circle around it.

Question number three asks you to identify which one of the three targets downrange was shot at. The one on your left, the one in the middle, or the one on your right. What indications can you use to tell? Maybe you'll see the tracer pass closest to one of the targets. Maybe you'll see a puff of dust where the bullet strikes the ground. Use whatever indications are available to help you decide. If you really can't tell, if you don't see anything that helps you choose, then draw a circle around the answer "couldn't tell." In question four, again we ask you how sure you are. If you're sure it was the target on the right, draw a circle around "sure." If you're fairly sure, draw a circle around "fairly sure." And so on. If you couldn't tell which target was shot at, draw a circle around the answer "no idea." Do you have any questions?

After you have seen 8 rounds from one OP, we will stop firing for about 2 minutes and ask you to move to your next OP. Every 9th page in your observation booklet will tell you which OP to go to next. OK. Let's try one round for practice. Stay in this general area, but move laterally to a position from which you can see downrange. The demonstrator located to your right front will fire one round at my command. This is a practice round. Observers watch the range.

(Demonstrator fires one round of M62 tracer approximately 2 meters to the left of the left target.)

All right. If you'll move back together again. What kind of ammo was that? How sure are you? Which target was engaged? How sure are you? OK, that's the procedure. Are there any questions? During the actual test, please do not discuss your answers with anyone else.

At this time, we will pass out to you a vision test card, a pencil, and an observation booklet. Please put your name on the cover of the booklet, and then fill out the right-hand end of the vision test card. You'll find your test identification number on the front cover of your observation booklet. Today's date is 26 September 1972.

Will you now move as a group over to the stop sign and then let me have one man at a time at the vision test point.

ORIENTATION 2

You men are about to participate as observers in a test of tracer ammunition. An ordinary tracer, what we call a "standard" tracer—as you'll recall from your training—is a round of ammunition in which a cavity on the rear of the bullet has been filled with a chemical material which burns as the bullet flies through the air.

The U. S. Army has been making tracer ammunition since World War I. We've made a lot of different types. And we're continuing to experiment with <u>new</u> types. We have some to show you today. The purpose of this test is to find out how some of the different tracer compounds compare with one another on two important measures of performance: detection and use. In a moment, I'll discuss with you how we measure that performance and how we will conduct the test.

First, some words on safety: If you will look to your front, you will see the firing/observing line. It is located on that sand berm and marked by engineer tape. At no time move forward of that tape. I repeat: at no time move forward of the engineer tape. Second, the weapons on this range will be fired electrically from the control point, which is located over there (point). Consequently, there are cables carrying electricity in several places on this range. Throughout this test you will be required to move along the firing line. When you move, please <u>walk</u>; do not run. And when you walk, please watch where you're going. We have the electric cables marked, and we would like you to step over them, not fall over them. Also, you will each get a chance to mount our five observation towers. We would like you to climb up and climb down carefully. NO PLFs, please. Finally, will you stay out of the ammo point which is located to your rear, and will you please not smoke while you are on this range. In the event of a weapon malfunction or other unscheduled event, will you please remain at your OP and listen to the PA set for instructions. Are there any questions so far?

OK, then let me tell you about this test. First, each of you will receive a quick vision check in that area over there. If you normally wear spectacles or contact lenses, please have them on or in when you report for your visual acuity check.

After we've verified that you can see, we will ask you to move to an observation point along the line to your front. Notice that the points are numbered. Number 1 is on the left, number 10 on the right. The towers are the odd-numbered positions, the chairs are the even-numbered points. After you go to the designated OP, look around for the code letter associated with that point. It will be printed on a blue 3 x 5 card like this. When you find it, write that letter in the appropriate place in the observation booklet we will issue you.

Then we'll begin the test. On the PA set we will tell you what round number we are about to fire. You turn in your observation booklet to the page with that number on it. Then you will hear the command, "Observers, watch the range." At that time, look downrange. You will see three white E-type silhouette targets side by side at a range of 400 meters. Then you will hear a round fired. One round. It will be fired at <u>one</u> of the three targets downrange. It may be a round of tracer or it may be a round of ball ammunition. After you've watched it, look in your observation booklet. The page will look like this (show chart).

We'd like you to answer the four questions. The first one says, "Was this round tracer or ball? Circle one." If you saw tracer, draw a circle around the word "tracer." If you didn't see tracer, draw a circle around the word "ball." Question two asks how sure you are about that last answer. If you're sure the round was a tracer or if you're sure it was a ball round, draw a circle around the word "sure." If you think it was, but you're not sure, draw a circle around "think so." There are five possible answers to this question. Pick just one, and draw a circle around it.

Question number three asks you to identify which one of the three targets downrange was shot at. The one on your left, the one in the middle, or the one on your right. What indications can you use to tell? Maybe you'll see the tracer pass closest to one of the targets. Maybe you'll see a puff of dust where the bullet strikes the ground. Use whatever indications are available to help you decide. If you really can't tell, if you don't see anything that helps you choose, then draw a circle around the answer "couldn't tell." In question four, again we ask you how sure you are. If you're sure it was the target on the right, draw a circle around "sure." If you're fairly sure, draw a circle around "fairly sure." And so on. If you couldn't tell which target was shot at, draw a circle around the answer "no idea." Do you have any questions?

After you have seen eight rounds from one OP, we will stop firing for about 2 minutes and ask you to move to your next OP. Every ninth page in your observation booklet will tell you which OP to go to next.

Now let me talk for a moment about some of the ammunition you'll see fired today. Standard tracer, as I told you earlier, emits light from the rear of the projectile as it travels downrange. The source of the light is the burning of the chemicals located at the cavity in the rear of the bullet. This is the way we have made tracer for years.

Today we want to test a new technique. It's called vapor trail tracer.[1] You have all seen vapor trails in the sky left by jet airplanes. The new type of tracer we're going to show you today leaves very much the same thing—only much, much smaller. Therefore, during the test, we want you to be alert to detect both types of tracer: the standard kind, which emits light, and the new kind, which leaves a vapor trail. At this time, will you move in a group to the firing line and take up a position from which you have a clear view of the range and the three targets.

Watch now as the demonstrator fires first one round of standard tracer from the M14 rifle.

(Fire one round of M62 tracer.)

Now observe as he fires a round of the vapor trail tracer.

(Fire one round of Super-Heavy Kotagun Red.)

How many of you saw the trace? How many of you think you saw it or saw something?

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[1]Although adequately descriptive of the phenomenon, this statement is not known to be accurate. The precise nature of the visual stimulus is not presently known to the Human Engineering Laboratory.

OK, let's try another round.

(Fire one round of Super-Heavy Kotagun Red.)

How many of you saw that one? How sure are you? Which target do you think was engaged? How sure are you about that? All right, watch another round.

(Fire one round of Super-Heavy Kotagun Red.)

Practice to yourself answering the four questions on the chart. Which answers would you circle? OK, here's our last demonstration round of the vapor trail tracer.

(Fire one round of Super-Heavy Kotagun Red.)

All right. If you'll move back together again. What kind of ammo was that? How sure are you? Which target was engaged? How sure are you? OK, that's the procedure. Are there any questions? During the actual test, please do not discuss your answers with anyone else.

At this time, we will pass out to you a vision test card, a pencil, and an observation booklet. Please put your name on the cover of the booklet, and then fill out the right-hand end of the vision test card. You'll find your test identification number on the front cover of your observation booklet. Today's date is 27 September 1972.

Will you now move as a group over to the stop sign and then let me have one man at a time at the vision test point.

APPENDIX C

TEST INSTRUCTIONS

At this time, check to see that you are located at the OP number that is marked on the GO TO page in your booklet just before the page for round number______.

Down in the right-hand corner of that page, copy the code letter of your OP in the box by the arrow.

Now turn in your booklets to the page for round number_____.

Observers, WATCH THE RANGE.

[Fire one round.]

When you have recorded your answers, turn to the page for round number_____.

Observers, WATCH THE RANGE.

[Fire one round.]

[After rounds 8, 16, 24, 32, 40, 48, 56, 64 and 72 say--]

Turn to the next page in your booklet.

It should tell you to which OP to go next.

Move carefully to that OP at this time.